The Open University

Science
S382 Astrophysics

S382

Tutor-Marked Assignment 05

Contents **Cut-off date**

Please send all your answers to the tutor-marked assignment (TMA) to reach your tutor by 12 noon (UK local time) on or before the cut-off date shown on the S382 website. Your TMAs should be submitted through the eTMA system unless there are difficulties which prevent you from doing so. In these circumstances, you must negotiate with your tutor to get their agreement to submit your assignment on paper. The eTMA system allows for eTMA submission directly to the university 24 hours a day, and either gives you confirmation that your eTMA has been submitted successfully or, if there has been a problem, an error message informing you of the problem and what steps you can take to overcome it. If you submit online you must keep your receipt code in case you need to prove successful submission.

General information about policy and procedure is in the *Assessment Handbook* which you can access from StudentHome. However, there are a number of ways in which S382 eTMA submission differs from what is described there. These are described in the document *Producing eTMAs for Level 3 physics and astronomy modules* on the S382 website. See also the S382 *Introduction and Guide* for module-specific information.

Of particular importance is the test submission, TMA 00. This will enable you to familiarize yourself with the system and allow your tutor to check that the format in which you save your TMAs is compatible with their own computer software. It is your responsibility to make sure that you submit documents in a compatible format and we strongly recommend that you submit TMA 00. TMAs submitted in an incorrect format may not be marked.

If you are submitting a paper copy, please allow sufficient time in the post for the assignment to reach its destination on or before the cut-off date. We strongly advise you to use first-class post and to ask for proof of postage. Do not use recorded delivery or registered post as your tutor may not be in to receive it. Keep a copy of the assignment in case it goes astray in the post. You should also include an appropriately completed assignment form (PT3). You will find instructions on how to fill in the PT3 form in the *Assessment Handbook*. Remember to fill in the correct assignment number (05).

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2.1 PT/TeX

This fifth booklet provides some advice about submission of TMA answers as well as the questions for TMA 05. Although the marks for your assignments do not count directly towards your S382 result, they are an essential part of your learning and you are required to engage satisfactorily with them. Please refer to the S382 *Introduction and Guide* for additional information about the module assessment.

Assignment cut-off dates
The cut-off dates for the assignments provide an important element of pacing for your study of S382 and they are spread fairly uniformly through the year, leading up to the exam. **You should regard these dates as fixed points**. *Any extension to a TMA cut-off date requires prior permission from your tutor, which may not always be given. Extensions may be granted in exceptional circumstances but it will never be possible to have an extension of more than 3 weeks.* Your tutor will, of course, be willing to discuss with you the best strategies for catching up if you have fallen behind, and should be able to help with questions if you are stuck.

Marking of assignments
As explained in the *Introduction and Guide*, all the assignments for S382 are *formative*. They are designed to help with the teaching of the module not its assessment, and the scores you obtain for them *do not* count towards your overall grade. Nonetheless, **you are required to satisfactorily complete at least 8 out of 10 of the TMAs and iCMAs** in order to be considered for a grade based on the examinable assessment components (i.e. the exam covering Parts 1 and 3 of the module and the project portfolio covering Part 2 of the module).

The assignment questions allow you to demonstrate that you have achieved particular learning outcomes for the module. These learning outcomes are listed in Section 2 of the *Introduction and Guide*. They include knowledge and understanding of the module content, the ability to apply this knowledge and understanding to the solution of problems in astrophysics, the ability to explain concepts, phenomena and applications in astrophysics, and the ability to communicate effectively your solutions and explanations. In each assignment booklet we indicate which of the learning outcomes are assessed in the assignment, and which parts of the questions relate to which learning outcomes.

When commenting on your assignment answers, your tutor will be assessing the extent to which you have achieved the learning outcomes. This will include assessing whether you have got the correct answer, but also whether you have explained your reasoning, whether your answers are well-structured (both for numerical and discursive answers), and whether you have used correct terminology and notation, and so on. For each of the learning outcomes that are assessed, your tutor will allocate a descriptor to indicate your level of achievement, which will be one of: well demonstrated, demonstrated, just demonstrated, not quite demonstrated, not demonstrated (or not attempted).

Plagiarism
You are encouraged to discuss the S382 materials and assignment questions with other students, but the answers to the assignment questions must be your own work. This does not preclude you from making judicious use of material from other sources, but you must acknowledge such use by giving the author's name, the year of publication, the name of the publication in which it appears (or the website address), and the edition or volume number and the page number. However, there is no need to give references for standard equations in the S382 texts. You are advised to read the University's guidelines on plagiarism, see the *Introduction and Guide* for more details.

To check that all students are working in a fair and academically appropriate manner, the Open University is currently using some text-comparison software to detect potential cases of plagiarism in work that is submitted for assessment. Details of how this is implemented in this module are given on the S382 website.

Further general advice on answering S382 assignment questions is given with TMA 01.

TMA 05 CUT-OFF DATE: SEE S382 STUDY PLANNER

This assignment covers Chapters 5 and 6 of *Transiting Exoplanets*. It allows you to assess your ability to achieve the following learning outcomes:

Kn8: Knowledge and understanding of methods used in the detection and characterization of exoplanets, in particular the properties revealed by exoplanet transits.
C3: Derive and manipulate quantitative theoretical models of physical processes and to derive physical estimates.
C5: Critically evaluate arguments and data and formulate judgements in accordance with astrophysical theories and concepts.
Ky1: Organize and clearly present relevant information in response to defined tasks, including the expression of mathematical and scientific concepts using clear, concise and correct scientific prose.
Ky2: Learn from a variety of sources and media including material on the WWW and journal articles which are not specifically written for an undergraduate audience.
P1: Search for and download relevant information from the World Wide Web.

Question 1

(a) (**Learning Outcomes Kn8 and Ky1**)
Detailed radial velocity observations of the host star of a transiting exoplanet reveal the RV curve shown below. Measurements of the transit reveal that the inclination of the exoplanet orbit is $i = 90°$.

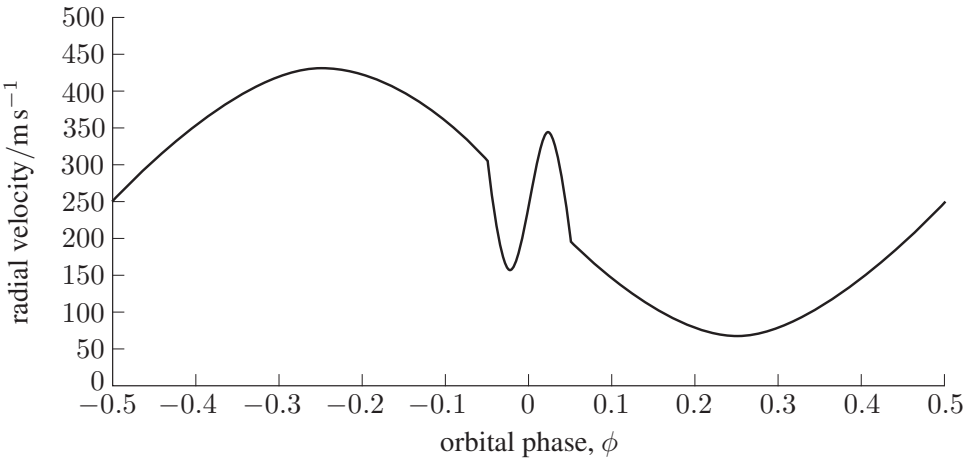

Figure 1 The radial velocity curve of the exoplanet host star referred to in part (a).

(i) State the name of the effect that gives rise to the RV excursions around orbital phase zero, and in no more than 300 words, explain how the deviations from a sinusoidal RV curve arise in this particular case. If you assume that the orientation of the stellar spin axis is $i_S = 90°$, what can you conclude about the relative alignment of the stellar spin and orbital angular momentum vectors in this case?

(ii) In a few sentences, explain how your answer to (i) might change if you could *not* assume that the orientation of the stellar spin axis has the value $i_S = 90°$.

(iii) In no more than 200 words, explain how the effect you have named and described in (i) might allow the detection and confirmation of terrestrial-mass exoplanets in Earth-like orbits around Sun-like stars that are otherwise unmeasurable.

(b) (**Learning Outcomes C3 and C5**)
When observing in the infrared at a wavelength of 18.0 μm, a secondary eclipse is observed in the system described in (a), with a depth of $\Delta F_{\rm SE}/F = 0.0025$. The radius of the star and planet are determined to be $R_* = 1.25\,{\rm R}_\odot$ and $R_{\rm P} = 1.15\,{\rm R}_{\rm J}$ respectively, whilst the radius of the circular orbit of the planet is $a = 0.028\,{\rm AU}$. You may assume that the Bond albedo of the planet is $A = 0.66$, that the wavelength-dependent geometric albedo $p_\lambda < 1$, that the effective temperature of the star is $T_{\rm eff} = 7200\,{\rm K}$, and that both the star and planet emit as black bodies (i.e. for the star $T_{\rm bright} = T_{\rm eff}$ at all wavelengths).

(i) Assuming that the reflection component from the planet may be neglected and that we are observing in a bandpass for which $hc/\lambda_{\rm c}kT_{\rm day} \ll 1$, combine Equations 6.4 and 6.14 to show that the fraction of the energy that is transported to the night side of the planet P, is less than 20%.

(ii) Given the value of P determined in (i), use Equations 6.4 and 6.5 to calculate the day side and night side equilibrium temperatures of the planet. How would the temperatures differ if energy were transported to the night side with maximum efficiency?

(iii) Explain whether the assumption in (i) concerning the value of $hc/\lambda_{\rm c}kT_{\rm day}$ is valid or not in this case.

(iv) Explain whether the assumption in (i) concerning the negligible reflection component is valid or not in this case. If it is not valid, what effect does its adoption have on the calculated temperatures?

(c) (**Learning Outcomes Ky2 and P1**)
Section 5.2 of the book reports the first detection of an exoplanet atmosphere in the ultraviolet, as a result of observing transits of HD 209458b at the wavelength of the Lyman-α absorption line. The paper reporting the results is by Vidal–Madjar et al. (2003) *Nature*, **422**, 143.

- Go to the website of the Smithsonian Astrophysical Observatory/NASA Astrophysics Data System (http://adsabs.harvard.edu/abstract_service.html) which you visited in an earlier Activity, and locate the entry for this paper.
- Click on the appropriate link to find a list of all the articles which *cite* this paper.
- From the list of articles you obtain, identify a more recent paper which also reports on ultraviolet spectroscopic measurements, but of a *different* transiting exoplanet, and read its abstract.

(i) In a few sentences, discuss why you think that searching amongst papers which cite the Vidal–Madjar et al. paper on HD 209458b is a good way to find other papers which also report on ultraviolet spectroscopic observations of a different transiting exoplanet.

(ii) State the reference (title, authors, publication details) for the paper you have identified.

(iii) State the name of the exoplanet which is the subject of the paper, and the nature of the observations that are reported in the paper, i.e. what telescope/instrument/wavelength range, etc.

(iv) In a few sentences, summarize the main conclusions of the paper in your own words.

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